MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support

WATER REUSE COMPONENT

ECONOMICS STUDY FOR WATER REUSE FOR AGRICULTURE AND/OR FORESTRY IN THE AMMAN-ZARQA HIGHLANDS

by

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Executive Summary

This summary contains the highlights of my consultancy, whose objective was to carry out a comprehensive economic and financial analysis for each of the irrigated agriculture based options for water reuse in the Amman-Zarqa basin[1]. During this phase I was required to evaluate the three options contained in ARD's Pre-feasibility study (ARD, Sept. 2000): namely, the Highlands Irrigation Project (Option HL#2a), Wadi Dhuleil and Khalidiyyeh Irrigation Project (Option HL#3), and Highlands Irrigation Distribution Network (Option HL#4).

The principle conclusion from this analysis is that unless much of the cost of the project can be justified as part of efforts to conserve groundwater resources in the highlands, or the cost of utilizing or disposing of the water downstream of As Samra proves to be expensive, these options are not profitable. If none of the costs, either capital or operating, are passed on to the farmers, the use of recycled water for irrigation is profitable.

Our approach to the economic analysis was to find out initially if one or more of the options would be in the national interest. To save time, we ranked the three options according to their expected profitability, and began with HL#2a because it's potential profit rate looked better than the other two. The two measures we used for ranking the three sites were the distance from the As Samra treatment plant and the amount of new irrigable land. The Pre-feasibility study was our source for investment and operating costs for the piped delivery systems; and this consultancy was to provide estimates of on-farm costs and benefits, as well as information dealing with drip irrigation, cropping choices, and so on. To provide a practical basis for our estimates, we assumed a farm size of 200 dunums, which may seem large by some standards, but not in the Highlands. Our sources of information included published reports, ARD-team knowledge, a visit to the Ministry of Agriculture, discussions with farmers, and a trip to the area. We relied solely on market values, without making adjustments to arrive at *shadow prices* (see Appendix A for explanation of this term).

We used this information to create spreadsheets so as to calculate rates of return for selected alternatives for the HL#2a site. The alternatives included three tests of economic feasibility from the national point of view, which included total project costs, and two tests of economic feasibility from the farmers' point of view, which included only the farmers' costs. Following are the findings:

- **national point of view:** the option is highly unprofitable: no rate of return calculation was necessary because the value of farmers' outputs failed to cover total project costs, i.e., those of the Government and the farmers;

[1] Source: my Work Description prepared by ARD.

- **farmers' point of view:** at a rate of return of 13 percent, the option is passably acceptable, provided farmers pay nothing to the Government;

- **farmers' point of view:** the rate of return to the farmers falls to 11.5 percent should the Government require them to pay a water fee of 15 fils per cubic meter; while this fee is similar to the fee Jordan Valley farmers pay, it would cover only a fifth of the project's O&M costs while contributing nothing to the investment in the pipeline.

Because of this lack of profitability, we found it unnecessary to test the profitability rates for HL#3 and HL#4 b ecause their profit potential in agriculture is less than that of HL#2a.

Rather than abandon consideration of these three options because of these findings about irrigated farming, they still could be considered for developing opportunities for conserving groundwater. In the body of this report, we address the Government's concern over future municipal water supply for the greater Amman area and the possibility of applying a *cost effectiveness* approach in evaluating alternative sources of supply. Water from the HL#4 area could be an important alternative, given the large amounts of groundwater being pumped there now.

So, the above are the essential results of our study. Following, in the body of the report, are sections that 1) support the selection of drip irrigation as the preferred method of irrigation, 2) consider farmers' possible choices of cropping patterns, and 3) report on rates farmers pay for water on Government projects. We did find drip irrigation to be a viable practice, in no small part because it is now being widely used throughout the country. But other ARD consultants warn of possible clogging problems because of algae and mineral deposits and the need for technical assistance. We settled on a cropping pattern for HL#2a that favors fruit crops over vegetables at the ratio of 85:15. Our choice rested on the prevalence of fruit production in the Highlands and the current restrictions on many types of vegetables. Rather than suggest specific crops to be grown on the schemes, we used representative values for revenues and variable costs. Finally, the prevalent rate of 15 fils per cubic meter, if the Government requires HL#2a farmers to pay a water fee, would cover only 20 percent of the O&M costs for the delivery system.

Introduction

Metropolitan Amman and the nearby industrial area are experiencing a water shortage that requires remedial action. One of these actions, which is the focus of this and related reports, is the substitution of recycled water for groundwater, thereby protecting groundwater for human consumption. This recycled water can be used for agricultural and industrial production or it can be allowed to flow to the Dead Sea. In agriculture, the recycled water could be advantageously used by three types of farmers. One type comprises those who find groundwater costing them more to pump due to falling groundwater tables or where rising salinity levels lowers crop yields. Another type comprises farmers whose groundwater is no longer available to them due to preempted use by others. The third type are those who wish to farm new areas or expand existing areas. The advantages to this last group is that it would be possible for them to farm where otherwise they could not or to continue farming at lower cost. The primary disadvantage is the presence of pathogens that restrict cropping choices and the ability to use recycled water for animal consumption. Another disadvantage, which this report does not address, is the potential of groundwater contamination from large-scale use in agriculture. Finally, an advantage of allowing recycled water flow to the Dead Sea is the preservation of this national resource, with its aesthetic and tourist values, by retarding the rate at which the water level is dropping.

This report is the first of ARD's consultancy to address the economic and financial implications of using recycled water from the treatment plant at As Samra for agricultural purposes in the Highlands. The ARD team identified three locations with suitable soils and climate then proceeded to develop sketch plans and estimates for their development. The nearest to the wastewater treatment plant is only five km to the east, while the furthest is 35 to 40 km to the northeast. More will be said about these three sites in a following section. While the focus of this report is on the Highlands, the results and procedures should help clarify some of the issues relating to recycled water use in for Wadi Zarqa and the Jordan Valley.

The body of this report provides 1) guiding principles for the economic and financial analyses, 2) additional detail on the recycled water delivery systems to the three highland options, 3) the order of analysis, 4) the choice of irrigation technology, 5) cropping possibilities, 6) water charges, 7) results of the analysis, and 8) conclusions and recommendations. Following that are references and supporting appendixes.

Guiding Principles of Benefit-cost Analysis

The approach to benefit-cost analysis applied in this report tended to follow the general procedures of the World Bank, and other international institutions, when appraising agricultural investments in the developing countries. That is, the analysis estimated benefits and costs according to their time of occurrence over the assumed project life, considered both the national and farmers' points of view, calculated rates of return as measures of likely profitability, and altered a few estimates in testing for sensitivity. While the initial plan was to first analyze all three options from a national and private perspective, this became unnecessary given the extremely high cost of delivering water to even the nearest location and the limited profitability of the crops to be grown. As a result, the analysis tested only the farmers' profitability rates. The reasoning will become apparent in the following sections of this report. For those interested, but unfamiliar with the subject, Appendix A provides a brief summary of several relevant benefit-cost concepts, as well as two texts on the subject.

Three Highland Possibilities

The Pre-feasibility Study (ARD, Sept. 2000) identified three options, as follows:

- An area labeled HL#2a located nearest the treatment plant some five km to the east on either side of the Khaw-Marfaq highway; estimated gross irrigable area is 10,200 dunums; and current land use is primarily rainfed barley.

- An area labeled HL#3 that is located about 14 km east of As Samra; estimated gross irrigable area is 8,000 dunums, of which the existing Dhuleil irrigation project covers 4,600 dunums; the existing system comprises deep pumping, delivery to an open reservoir, and distribution through lined distribution channels; while this system serves existing users, it would not be of much use for the recycled water scheme because of major differences in the means of irrigation; finally, reports from those encountered during a field trip to the area revealed that only a fourth of the system can be irrigated and that cropping patterns have moved away from vegetables to field crops

- An area labeled HL#4 that would serve an existing irrigated area some 35 to 40 km northeast of As Samra; estimates have not yet been made of the irrigable area, although it is considered extensive given current irrigation activity in the area; the water source is from deep wells operated primarily by large farmers who grow a variety of fruit, vegetable, and field crops.

ARD staff, after investigating the area and consulting the US Bureau of Reclamation classification system, have delimited the irrigable areas at HL#2a and HL#3 to soils considered moderately suited for irrigation. The staff did not evaluate soils at HL#4, but the history of successful farming in the area suggests that they are suitable for irrigation.

The options contain a common design of recycled water pumped from the reservoir through large-diameter steep pipe to an earthen storage reservoir and then distributed to farm plots. Farmers at the schemes would be responsible for on-farm investments, including land-leveling, distribution, and drainage, as well as cropping choices and farming operations. See the Pre-feasibility study report for Amman-Zarqa Highlands (Sept. 2000) for more details on the technical aspects of these options.

The Order of Analysis

The high cost of transmitting recycled water and the increasing distances when moving from HL#2a to HL#3 and from HL#3 to HL#4 suggest a logical sequence in the analysis of these three options. Land use at the three locations provides an additional basis for analysis. The greater distance to HL#3 coupled with less new land to be brought under irrigation there favor HL#2 over HL#3. And HL#3 enjoys distance and area advantages over HL#4. Since these three options are not mutually exclusive, accepting one does not preclude accepting another; but for analysis purposes, it makes sense to evaluate HL#3 only if HL#2 is economically attractive, and HL#4 only if HL#3 is attractive. Because, as will be shown below, HL#2 was not found to economically viable, neither would be HL#3 or HL#4. So analysis needed to proceed no further. At a later date, when consideration is given to alternative ways for preserving the groundwater supply, ARD might readdress the options of bring recycled water to these three locations, especially HL#4. The latter site is important because of the large amount of groundwater being pumped there.

Choice of Technology

After evaluating the alternatives of sprinkler and surface (e.g., furrow and flood) irrigation methods, the pre-feasibility study concluded that drip (also know as trickle) irrigation was the preferred method for the highland options. Efficiency of use (considering the costs of delivery) and safety (considering the health hazards of using recycled water) were the primary factors the ARD team used in reaching this conclusion. With proper management, drip irrigation can reach field application rates exceeding 90 percent--considerably more than either sprinkler or surface irrigation. Plants tend to receive the proper amount of water at the time needed, which translate into higher yields. Controlled water application also reduces weed growth within the rows and at the base of fruit trees. Fertigation, is the practice of applying agricultural chemicals directly with the water supply, is an added advantage of drip irrigation. And with limited and controlled amounts of water applied to the root zone, runoff and fertilizer loss are also reduced. By selecting this method, recycled water could be delivered to the plants' root zones by means of a completely enclosed system. Finally, farmers from the Jordan Valley to the Highlands are widely using drip irrigation; and materials are available from local manufacturers.

The major disadvantages of choosing drip irrigation using recycled water are the problems of algae and mineral deposits blocking the lines and emitters, as well as the need for good management and investments in filtering systems. These problems are pointed out by

Grattan (Oct., 2000) and in Vol. I of the Forward study (June, 2000) and are recognized by the ARD team. In fact, Grattan says, algae along with sediments found in the irrigation water supply can play havoc on drip irrigation systems and will require upgrades in existing filtration processes. And Hanson (ARD, Aug., 2000) recommends both a pilot program and more extension services to help farmers become more efficient irrigators and to help them overcome some of the problems common to drip irrigation. But farmers in some of the wadis downstream of the treatment plant and in the Jordan Valley have successfully adopted drip systems that use water emanating in part from the treatment plant.. The fact that only one-third of the farmers interviewed in a recent study there felt that clogged lines was their major problem suggests that drip irrigation can be viable. Another disadvantage of a different sort, is that drip irrigation is not suitable for field crops.

In time, more recycled water from As Samra will become available, as the population of greater Amman increases and if the hoped-for increase in daily per capita water consumption materializes. For example, the Pre-feasibility study shows total effluent discharged from As Samra growing from 56 million cubic meters for the current year to 176 million cubic meters by 2025. Should this scenario materialize, recycled water would then be much more abundant and the need to conserve recycled water for irrigation and other uses less pressing. This outcome would lessen the urgency of efficient on-farm application, which was one of the reasons supporting the selection of drip irrigation. Of course, health concerns will remain and the cost of recycled water delivery to the Highlands would still have to be considered when considering changes in on-farm technology.

Crop Choices

As noted, once the decision was made to use drip irrigation the possibility of irrigating field crops, such as wheat, barley, maize, and alfalfa, was eliminated. Add to that the Government's restriction on using recycled water to grow many vegetables that could be eaten in raw form and the list of possible crops reduces to fruit crops and those vegetables normally cooked before eaten. A major problem with vegetables is the difficulty in enforcing the selective restrictions. As in the Wadi Zarqa, the simplest approach for the Government in dealing with many small farmers is simply to forbid them from growing vegetables at all, even though some vegetables would not pose a danger to the public's health.

Assuming the Government and some growers, especially the larger ones, can agree on which vegetables grow using recycled water, the ARD team decided to include several of them as candidates, as well as fruit trees common to the Highlands. The listing below shows the predominant fruit and possibly qualifying vegetables for the governorates of Marfaq and Zarqa--the two governorates where HL#2a, HL#3, and HL#4 are located. (See Appendix B for more information about these and other crops in the two governorates.)

Crop	Total area (dunums)	Total production (metric tons)
Olives	115,450	8,520*
Apples	6,158	2,418
Sweet melons	4,318	7,922
Summer squash	2,177	2,471
Summer eggplant	1,514	2,225
Dry onions	562	1,885
Potatoes	456	1,028

* 1999 was the off-year in terms of the "alternate bearing" cycle, in which a good production year is followed by a poor one.

The significance of this listing is the predominance of the area planted in fruit trees over that of vegetables. This finding, together with the Government's restrictions on vegetable production, led the ARD team assume an 85-15 percent mix between fruit and vegetables. These percentages reflect our judgment on what might happen in the area should one or more of the schemes be built. This judgment weighed vegetable's generally greater profitability, as well as immediacy of implementation, against the predominance of fruit trees in the area and the lack of Governmental restrictions. The team did not interview potential farmers, at this stage of the analysis, as to which crops they might plan to grow were one or more of the options to materialize.

Water Charges

Government policy is to charge farmers for the water provided by Government-funded projects. The Jordan Valley Authority charges farmers 15 fils per cubic meter for water it supplies farmers from the King Abdullah Canal. A farmer at the Dhuleil irrigation scheme told ARD staff that he pays about 13 fils per cubic meter for the water he receives to flood-irrigating his alfalfa fields. This amount, given our rough calculations, is surprisingly close to that paid by farmers in the Jordan Valley. In contrast, the Government does not currently tax farmers who have their own wells and pump for accessing groundwater.

Consequently, farmers who might participate in the one of the Highland options could be expected to pay about 15 fils per cubic meter. The impact of this charge on farmer incentives would depend largely on the profitability of farming there, as well as farmers' past experiences with Government-funded water supplies. The results of ARD's forthcoming rapid appraisal study in the Highlands ought to provide some insight into farmers' willingness there to pay water charges of this magnitude. One suspects that many of them, who have relatively large holdings (200 dunums or more) would have the capacity to pay.

Analysis

This analysis of the Highland options focuses on the investments and agricultural activities assumed for HL#2a. The results for HL#2a, which turn out negatively, form the basis for rejecting the options at HL#3 and HL#4. The analytical approach used for this consultancy follows the general procedures summarized in the section on guiding principles and detailed in Appendix A. Fig. 1 provides the values used in carrying out rate of return calculations; Appendix D provides supporting detail; and the spreadsheets appearing in Appendix Tables E-1 to E-5 provide the format leading to the actual calculations themselves. (As it turned out only two of the tables produced an actual rate of return; the reason being that undiscounted cash flows exceeded the inflows.) Below are short, descriptive sections on investment and crop selection and a discussion of the results.

Investment

The investment comprises two parts: that of the Government in bring recycled water to the HL#2a site and that of the farmers there. The Pre-feasibility study (ARD, Sept., 2000) provided the basis for the former and this consultancy provided estimates for the latter. Fig. 1 shows the breakdown of the Government's investment, with significant amounts for pumping stations, conveyance pipe, earthen storage, and roads and drains. Engineering, design, supervision, and an allowance for unforeseen expenditures are standard percentages. Except for distribution pipes and values, we have assumed that all of the pumping system and ancillary works will last the entire project life. The 40 year project life reflect a relatively long longevity and is a figure commonly applied for this type of investment. Whether or not facilities actually last this long, or longer, normally has little impact on the investment decision.

As concerns the investments in farmers' facilities, several comments can be made. The first concerns farm size. We chose 200 dunums as an efficient size of farm that had a chance of operating profitably and would not be unlike other farms in the area and to the north. The number of farmers was dictated by the gross area of 10,200 dunums, less ten percent to allow for roads, drainage, and other facilities. This net area of 9,180 dunums divided by 200 yields the 46 farms indicated in Fig. 1. Second, the previous section on crop choices gave our reasons for favoring fruit crops over vegetable crops. But after finding the inadequacy of net benefits from this cropping mix, we tested the profitability using 25 percent of the area in vegetables and the remaining 75 percent in fruit crops. This change improved the net benefits somewhat, but not enough to bring about a profitable result. (See Appendix C for the investment for HL#2a under this assumption.) Third, detailed comments about these on-farm investments can be found in Appendix D.

	Life	Amount ('000 JD)**
Government's facilities		
Site preparation	40	150
Pump station for conveyance	40	1,035
Pump station for distribution	40	350
Conveyance piping & fixtures	40	2,839
Earthen storage tank	40	1,395
Distribution pipes & valves	20	2,499
Roads & drains	40	2,193
Field leveling	40	87
Subtotal		10,548
Mobiliz'n & demobiliz'n @ 3% of Subtotal		316
Eng planning, design & superv'n @ 20% of Subtotal		2,110
Sub-subtotal		12,974
Unforeseen expenditures @ 10% of Sub-subtotal		1,297
Total		14,271
Farmers' facilities@ 46--200 dunum farms		
Own filter tanks and controls 15,000	20	690
Drip lines & nozzles		
170 dunums in fruit trees @ 500/ha = 8,500	5	390
30 dunums in vegetables @ 1,340/ha = 4,000	5	180
Mulching plastic @ 600	5	30
Field contouring @ 1,100	40	50
Field roads & drains @ 2,200	40	100
Farm buildings @ 5,000	40	230
Farm equipment * @ 30,000	10	1,380
Farm truck @ 15,000	10	690
Nonseasonal working capital @ 7,500	--	350
Subtotal		4,090
Planning, design superv'n @ 5% of Subtotal		200
Sub-subtotal		4,290
Unforseen expenditures @ 10% of sub-Subtotal		430
Total @102,600 per farm		4,720

* tractor, plows, harrow, pumps, hand tools
**2000 values

Figure 1. Investment for HL#2a (85% fruit trees, 15% vegetables)

Crop Selection

This section considers in more detail the types of crops that could be grown profitably at HL#2a. The choices are influenced by what is grown in the Highlands now, by the choice of drip technology, and by Government restrictions over vegetable production. Area planted to fruit trees dominate other crop types in the governorates of Mafraq and Zarqa: in 1999, according to the Annual Agricultural Statistics, the area planted in fruit trees was 135,000 dunums compared with the area planted in summer vegetables of 79,000 dunums and that planted in autumn vegetables of only 8,000 dunums. The area planted to field crops is not relevant because they are unsuited for drip irrigation.

Next, we needed to learn something about the general profitability of fruit and vegetable production. Data were not readily available during this consultancy on crop budgets in the Highlands. So, we relied on data for the Jordan Valley as contained in Vol. V of the Forward reports (Fardous, June 2000). The report's tables show farm-gate values along with variable and fixed costs of production for a wide range of vegetables and a few tree crops, such as citrus and dates. The value of output was simply yield times price at the farmer's gate. The variable costs of production were broken down according to charges for water, seed or seedlings, fertilizers and other agricultural chemicals, machinery charges, and labor. The result gives a gross margin, before fixed costs of land rent, interest on working capital, and miscellaneous other costs. For our estimates, we omitted water charges, machinery costs, and land rent, for the following reasons: we wished, in our analysis, to consider water charges as a separate variable, since the cost of supplying water is covered by the pipeline investment for HL#2a; similarly, machinery costs are included in our estimate of the farmers' investments; and we left out land rent, because we considered existing productivity of the land in a separate calculation. Since Vol. V records data according to stage office, water quality, irrigation technology, and amount of leaching, we were able to match some of the conditions in the Highlands with those in the Jordan Valley.

Without going into all of the details behind our estimates, we settled on net annual returns to fruit production of JD225/dunum,[2] once full production is reached, and to a combined

[2] As noted elsewhere, this estimate of the net returns from fruit are not for a particular crop; but it is doubtful that olives, while popular in the Highlands, would be one of the choices due to the relatively low returns it produces. By way of comparison data supplied by Eng. Yasser Nazzal show annual net returns of JD242/dunum from citrus, JD370/dunum from bananas, and JD358/dunum from grapes, but only JD49 from olives.

summer and winter vegetable production of JD325/dunum. The output from vegetable production could occur shortly after farmers complete their on-farm investments. In contrast, fruit output will build up rather slowly, which can be seen from any of Appendix Tables E-1 to E-5. The benefits shown in these appendix tables are somewhat lower than indicated by these per dunum returns because of interest paid on seasonal working capital and some fallow for the vegetable crops.

from bananas, and JD 358/dunum from grapes, but only JD 49 from olives.

Results

We used the foregoing estimates of costs and benefits to complete five separate spreadsheet matrices that, when summed year-by-year and discounted, would normally yield a profitability measure called the *internal rate of return*, or more simply the *rate of return*. However, because total costs exceeded revenues when considering the national point of view, no discounting was needed. The results show an outright loss to the economy should the Government undertake any of the three options. On the other hand, should the Government not require participating farmers to pay anything, or just the common 15 fils per cubic meter of water, then the project appears to be marginally acceptable to the farmers. Below, is more information about these five feasibility tests.

- Appendix Table E-1 shows total costs exceeding benefits by JD19.8 million over the assumed life of 40 years. This result means the project is highly unprofitable.

- Appendix Table E-2 considers the possibility of increasing the amount of vegetable production to 25 percent of the irrigable area. This change improves the situation only slightly: costs still exceeded benefits by JD15.9 million.

- Appendix Table E-3 probes in another direction by looking at how much of a reduction in annual O&M costs would be needed for the project to just break even, or in other words have a rate of return equaling zero. The table shows annual O&M costs would have to be reduced to JD436,000 per year, which is 46 percent of the original estimate of JD954,000 per year. This reduction would mean an annual O&M charge of only 2.3 percent of investment cost. The ARD staff member who prepared the Pre-feasibility study said that he felt the original estimate of five percent was a sound figure and that, given the large amount of pumping required, annual O&M costs could not be safely reduced. Thus, the project remains unattractive economically.

- Appendix Table E-4 considers only the farmers' costs and benefits. Were farmers to receive recycled water at the HL#2a site without any obligations to repay the Government, their rate of return for their own investment would be 13 percent. Some farmers might consider this profitability rate acceptable, but others might not give the inherent risks of this scheme.

- Finally, Appendix Table E-5 shows that the farmers' rate of return would drop to 11.5 percent if they were to pay the going rate of 15 fils per cubic meter of water. Moreover, for the HL#2a option, the amount of money paid to the Government under this arrangement would cover only 20 percent of the pipeline system's O&M costs and none of its capital costs.[3]

[3] Fruit trees require about 1,500 cu m/dunum/year and vegetables require about 500 cu

Groundwater Conservation

The foregoing analysis showed that the Highland irrigation options would not be economic from the national point of view. And HL#2a would only be marginally attractive to farmers, provided they do not have to pay a water fee. But this does not mean that none of the options has merit when the national interest is in conserving groundwater for future municipal use. Providing water, privately or publicly, for human consumption is one of the most fundamental of government responsibilities. And HL#4, where substantial private pumping now occurs, offers the possibility of preserving substantial amounts of groundwater if farmers can be persuaded to switch to recycled water. Whether or not this possibility is worthwhile for the Government to consider depends on the farmers' willingness to accept recycled water, the potential for aquifer contamination from the recycled water, the cost of bringing recycled water to the area and the resulting benefits to participating farmers, and other potential sources of municipal water supply.

As noted, ARD's survey of Highland farmers will provide insight on farmers' willingness to accept recycled water in the HL#4 area. Some farmers have already expressed their interest in doing so, provided the Government does not ask them to pay more for the water than do those in the Jordan Valley. Also, if the watertable in the area continues to fall, more and more farmers will find pumping costs excessive thereby becoming more receptive to recycled water use than they are now. Potential contamination of the aquifer is a technical question that is more difficult to answer without further study. The Pre-feasibility study contains cost estimates for constructing and operating the pipeline and, although on-farm costs and benefits are not now known, they could be estimated in the same way as for HL#2a. Finally, if the Ministry of Water and Irrigation so desires, ARD could investigate alternative sources of municipal water supply.

Important in considering this approach to municipal water supply is an understanding of the difficulty of attaching a value to critically low levels of water supply. To be sure, surveys can be carried out that ask households how much they would be willing to pay for water. But if the response falls short of what it costs to secure some socially acceptable minimum supply, then alternative analytical techniques are needed. One of these techniques is called cost-effectiveness analysis. This technique requires identifying least-cost solutions for alternative levels of supply and letting decision makers decide what amount of water

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m/dunum/ season. For the project area of 9,180 dunums with 85% in fruit trees and 15% in vegetables, the annual water requirements would be 13.1 million cu m. At 15 fils per cu m, the Government would collect only JD196,000 per year. That compared with annual O&M cost of JD954,000 yields 20.6 percent.

best suits the country's interests. Their choice depends on their preferences for meeting this basic need set against the monetary resources at their disposal.

Conclusions

The foregoing spreadsheet analysis leaves little doubt about the economic viability of the three options from a national perspective: all three options are not economically attractive. On the other hand, farmers might be interested in investing were they not required to cover even a small portion of the cost of the project to the Government. Under these conditions the Government would be heavily subsidizing relatively wealthy farmers to increase agricultural production. Undoubtedly, the country offers other alternatives yielding much higher rates of return, or contributing far more to national welfare, than do these three agricultural options.

Should the Government continue to pursue its goal of preserving the country's groundwater reserves, both for near-term additions to the municipal water supply for greater Amman or for long-term objectives, then the HL#4 option probably offers the best opportunity out of the three considered in the Pre-feasibility report. We did not study this alternative, since that is the subject of ARD's groundwater component.

Appendix A

Some Principles of Benefit-cost Analysis

The approach to the economic and financial analyses used in this report follows the general concepts of benefit-cost analysis as recommended by international organizations such as the World Bank, but adapted to the particular situation at hand. Regardless of the complexity of analysis, a few guiding principles should be kept in mind. Following is a summary description of some, but certainly not all, of the more relevant concepts of this analytical approach. They include comments on the use of benefit-cost analyses, the need for accurate technical information, the meaning of economic and financial analyses from the national and private perspectives, considering the situation with and without the proposed investment, the so-called time value of money and two decision rules, sensitivity testing, and shadow pricing.

Most important perhaps, especially for those not overly familiar with benefit-cost analyses, is an understanding about the use of the analysis. It is intended to be a decision-making tool that provides insight into the relative merits of alternative investments, or more simply stated, to separate good investments from poor ones. With this in mind, it is only important to understand the general nature of the investment, not to require engineering designs and construction standards. Thus, in this case, it is important to know the types of crops and their general level of profitability, but not which crops ought to be grown and what crop rotations to follow.

Without contradicting the foregoing, it remains critical that the economic and financial analyses be built on fundamentally sound thinking about how an investment would function. This means that the analysts must spend considerable time in conceptualizing the scheme to make sure that it has a chance of functioning more or less as planned; or, that technical adjustments can be made to accomplish the same result without greatly changing the relationship between costs and benefits.

Within the context of benefit-cost analysis the approach needs to consider the *economic* and *financial* situation form the *national* and *private* points of view:

C The aim of an *economic* analysis is to learn if some proposal makes wise use of the required resources; otherwise, they should be used elsewhere.

C The *financial* analysis deals with money; it=s purpose is to learn whether the investor has the cash with which to carry out an investment. Options for investment can be many, but if the required cash is not available when needed, the investments cannot be undertaken.

- The *national* perspective in this study is the Government of Jordan. The purpose of an *economic* analysis from the national perspective would be, in this case, to find out whether one or more of the wastewater options is in the national interest; and, if so, what the monetary requirements and cash receipts might be in terms of local and foreign currencies.

- The *private* perspective in this study is that of the farmers who would participate in one of the wastewater delivery options. The results of the *economic* analysis would be to indicate whether their on-farm investments would yield an adequate return. The *financial* analysis would indicate the adequacy of cash for investment and operations, given crop revenues, access to credit, and other financial sources.

- The foregoing come into play, as will be seen later, in deciding on the inclusion or exclusion of land purchases and taxes, imposition of water rates, provision for contingencies, etc.

Another principle is that of considering what the situation at the development site would be *with* and *without* the investment. As expected, the *with* situation represents what might occur were the investment undertaken; the *without* situation represents what might occur if the investment not undertaken. The difference in these two situations measures the net benefits and costs attributable to the investment.

The so-called *time-value-of-money* is another concept that underlies the approach to benefit-cost analysis. The interpretation is simply that a given amount of money, or some physical resource, is worth more today than in the future, for a variety of reasons one of which is one=s ability to invest the resource and receive a gain from its investment. Adjustment for amounts that occur at different times is through an interest rate, sometimes called discounting (i.e., by converting a future amount to a present amount). Various decision rules can be used, the most popular of which are the *net present worth* and the *rate of return*. The former converts all future values to the present, after discounting by an appropriate interest rate. A positive value means an investment is acceptable. The latter searches for an interest rate that brings the *net present value* to zero. That interest rate is then compared with some minimally required interest rate, sometimes called the *minimum attractive rate of return*. Any *rate of return* that equals or exceeds the *minimum attractive rate of return* is considered acceptable.

Because one cannot predict the future with certainty, an important component of benefit-cost analysis involves *sensitivity* testing. Essentially, this is finding out what happens to the results when one or more of the more important factors contained in the analysis is changed.

Finally, adjustments to *market* prices are sometimes needed to account for important deviations from, what economists call, *real* prices. The latter reflect an item's true value to the economy rather than the price it commands in the market place. For example, when an economy contains large unemployment, restricts foreign exchange, and influences prices through controls and subsidies, the prices found in the market place obscure what the items are worth to the economy. The adjusted value are called *shadow* prices, or sometimes *accounting* prices.

Many texts are available on benefit-cost analysis. One widely available pertaining to agriculture is that on the Economic Analysis of Agricultural Projects by Price Gittinger of the World Bank. Another of long-standing recognition is the Principles of Engineering Economy by Grant and Ireson. See References for the dates and publishers.

Appendix B
Potential Crops Based on Production at Marfaq & Zarqa Governorates during 1999

Potential Crops		Mafraq Area dunum	Production MT	Zarqa Area dunum	Production MT	Total Area dunum	Production MT	Ranking Area dunum	Production MT
Apples		4695	2238	1463	180	6158	2418	2	4
Broad beans	Summer	0	0	40	32	40	32		
Broad beans	Winter	0	0	130	65	130	65		
Cucumbers	Summer	186	1078	0	0	186	1078		7
Dates		5	8	123	81	128	89		
Eggplant	Summer	225	364	1289	1861	1514	2225	5	5
Eggplant	Winter	0	0	4	4	4	4	5	5
Garlic		125	113	295	377	420	490		
J_Malok	Summer	50	113	15	1	65	114		
Melons,swt	Summer	1123	1969	3195	5953	4318	7922	3	2
Olives		71472	3865*	43978	4655*	115450	0	1	1
Onions, dry	Summer	500	1825	0	0	500	1825	6	6
	Winter	0	0	62	60	62	60	6	6
Potatoes	Summer	48	110	88	198	136	308	7	
	Winter	80	200	340	520	420	720	7	
Squash	Summer	587	482	1590	1989	2177	2471	4	3

*Note: 1999 was the off year in terms of the "alterating bearing" cycle. in which good production years are followed by poor ones.

Appendix C
Investment for HL#2a
(75% fruit trees, 25% vegetables)

	Life	Amount (1000 JD, 2000 values)
Government=s facilities		
Site preparation	40	150
Pump station for conveyance	40	1,035
Pump station for distribution	40	350
Conveyance piping & fixtures	40	2,839
Earthen storage tank	40	1,395
Distribution pipes & valves	20	2,499
Roads & drains	40	2,193
Field leveling	40	87
Subtotal		10,548
Mobiliz=n & demobiliz=n @ 3% of Subtotal		316
Eng planning, design & superv=n @ 20% of Subtotal		2,110
Sub-subtotal		12,974
Unforeseen expenditures @ 10% of Sub-subtotal		1,297
Total		14,271
Farmers= facilities@ 46--200 dunum farms		
Own filter tanks and controls 15,000	20	690
Drip lines & nozzles		
150 dunums in fruit trees @ 500/ha = 7,500	5	350
50 dunums in vegetables @ 1,340/ha = 6,700	5	310
Mulching plastic @ 1,100	5	50
Field contouring @ 1,100	40	50
Field roads & drains @ 2,200	40	100
Farm buildings @ 5,000	40	230
Farm equipment * @ 30,000	10	1,380
Farm truck @ 15,000	10	690
Nonseasonal working capital @ 7,500	--	350
Subtotal		4,200
Planning, design superv=n @ 5% of Subtotal		210
Sub-subtotal		4,410
Unforseen expenditures @ 10% of sub-Subtotal		440
Total @102,600 per farm		4,850

* tractor, plows, harrow, pumps, hand tools

Appendix D
Explanation of Investment Costs

Following are explanations of the cost items going into the Government and farmers= portion of the project.

Government Investment

This analysis modified the figures in the Pre-feasibility study by 1) eliminating the costs of land acquisition and the application system and 2) reducing contingencies from 20 percent to 10 percent.

C Instead of counting the cost of *land acquisition*, we estimated the productive value of the land in its current use. Rainfed barley appears to be the crop most likely grown in the project area. Values from the Annual Agricultural Statistics report for 1999 show that gross margins for barley are on the order of JD20 per dunum and that only two percent of area planted was actually harvested. Applying these values to the project=s gross area of 10,200 dunums yields only JD4,000 per year, which is negligible compared with the proposed investment.

C We removed *land application* cost of JD1,000,000 because that was a provision figure for farm investment, which were to be revised by this consultancy.

C Providing 20 percent for design and cost *contingencies* is commonly applied by engineering consulting firms. Typically this amount covers both unforeseen expenditures and financial protection. The latter refers to the investor=s desire to provide financial coverage should cost overruns occur. By providing more money than would be needed under most of the possible outcomes, the estimator is making sure that those financing the project will not have to back to the funding agency for additional funding. Thus, such as a contingency factor actually overstates an investment=s most likely outcome. As such it should be removed. On the other hand, unforeseen expenditures represent real costs and are a legitimate part of benefit-cost analyses.

Besides the above changes to the Pre-feasibility estimates, we estimated the construction schedule as covering two years and that the expenditure rate occurs as 20 percent during the first six months, 50 percent around the end of the first year, and the remaining 30 percent towards the end of the second year. These percentages applied to the total investment show up in the rate of return tables in Appendixes E-1 to E-5. AYear zero@ shown there represents the beginning of the project period.

On-farm Investment

Following is a line-by-line explanation of the items making up the farmer=s investment. These estimates can be substantially refined with further study; but we believe them sufficient at this stage of the analysis.

- C *Filter tanks and controls*: used the recommendations of Fardous, Grattan, and Hanson (see References) about the need to provide filtering equipment; the estimated amount of JD15,000 per farm is simply a rough estimate.

- C *Drip lines and nozzles*: based on contractor estimates per dunum plus our estimates of six meter spacings for fruit trees (see Appendix Table D-1) and 80 cm spacings for vegetables, as well as amounts for headers that feed the drip lines; our derived estimates of costs per linear meter of drip line are 260 fils for fruit trees and 90 fils for vegetables. A possible explanation for the lower costs of lines for vegetables, based on our field observations, is that the tree lines have two nozzles per tree, whereas the vegetable lines feed water to the soil through small openings in the line.

- C *Mulching plastic*: used between vegetable rows to reduce evaporation; a rough estimate of a small value.

- C *Field contouring*: farmers will need to further level and shape their fields; taken as some value less than the Pre-feasibility=s estimate for this item.

- C *Field roads and drains*: these costs ought to be modest given the large cost listed under Government facilities; assumed five percent of the latter.

- C *Farm buildings*: a modest amount for one or two small structures; this recognizes the Government=s restriction of large buildings on irrigable land.

- C *Farm truck*: assumes farmers will need some means of hauling supplies and produce; this amount should allow the farmer to purchase the type of small pickup truck common to the area.

- C *Nonseasonal working capital*: this is the amount permanently tied up in the business; the amount is a crude guess as to what the farmer might need; the cost of seasonal capital is included in the variable costs of cropping through an annualized interest rate of 12 percent.

Appendix Table D-1
Tree Spacings in the Highlands

Appendix Table D-1. Tree Spacings in the Highlands

Crops	Product'n MT	Number of Trees	Trees per Dunum	Row Spacing M
Citrus	1,264	68,952	31	5.6
Olives	36,707	8,235,000	13	3.6
Grapes	13,900	1,871,594	55	7.4
Fig	1,534	155,709	29	5.4
Almonds	1,067	173,957	37	6.1
Peaches	10,322	649,313	42	6.5
Plums/prunes	3,793	268,560	42	6.4
Apricots	3,195	332,111	43	6.6
Apple	28,907	2,592,307	69	8.3
Pomgranats	1,582	98,154	37	6.1
Pears	941	119,204	46	6.8
Guava	306	20,725	44	6.7
Date palm	468	16,355	14	3.7
Nectarines	1,029	53,062	44	6.6
Cherry	521	79,247	42	6.5
Averages			39.2	6.2

Source: Annual Agricultural Statistics 1999, Table 6.

APPENDIX E

RATE OF RETURN CALCULATIONS

Appendix Table E-1. Rate of Return Calculations for HL#2a. (000 JD)
(85% fruit trees; 15% vegetables)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gov't investment	-2831	-7078	-4362														
Energy costs			-105	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294
O&M			-340	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954
Gov't replacem't pipes & valves																	
Engr'g design & super @ 20%																	
Unforseen expend @ 10%																	
On-farm investment			-4370														
On-farm replacement																	
Own filter tanks, etc.																	
Trickle lines, mulching, ec.								-600					-600				
Farm equip, truck													-2070				
Working capital			-350														
(85% fruit trees; 15% vegetables)								-30					-130				
Year	0	1	2	3	4	5	6	-60					-270				
Crop establishment			-1050	-1050													
Total investment	-2831	-7078	#####	-2298	-1248	-1248	-1248	-1938	-1248	-1248	-1248	-1248	-4318	-1248	-1248	-1248	-1248
Net benefits from fruit trees					-280	-280	-70	385	1050	1505	1575	1575	1575	1575	1575	1575	1575
Net benefits from vegetables			130	365	365	365	365	365	365	365	365	365	365	365	365	365	365
Net cash flow	-2831	-7078	#####	-1933	-1163	-1163	-953	-1188	167	622	692	692	-2378	692	692	692	692

Note: excludes estimates of current dryland production and extension services because of their small magnitude ; see text for a discussion.

Appendix Table E -2. Rate of Return Calculations for HL #2a. (000 JD)
(75% fruit trees; 25% vegetables)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gov't investment	-2831	-7078	-4362												
Energy costs			-105	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294
O&M			-340	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954	-954
Gov't replacem't pipes & valves															
Engr'g design & super @ 20%															
Unforseen expend @ 10%															
On-farm investment			-4500												
On-farm replacement															
Own filter tanks, etc.															
Trickle lines, mulching, ec.								710					-710		
Farm equip, truck													-2070		
Working capital			-350												
Planning & design @ 5%								-40					-140		
Unforseen expenditures 10%								-70					-280		
Crop establishment			-1050	-1050											
Total investment	-2831	-7078	-10707	-2298	-1248	-1248	-1248	-648	-1248	-1248	-1248	-1248	-4448	-1248	-1248
Net benefits from fruit trees					-250	-250	-60	340	930	1330	1390	1390	1390	1390	1390
Net benefits from vegetables			220	615	615	615	615	615	615	615	615	615	615	615	615
Net cash flow	-2831	-7078	-10487	-1683	-883	-883	-693	307	297	697	757	757	-2443	757	757

Note : excludes estimates of current dryland production and extension services because of their small magnitude ; see text for a discussion.

Appendix Table E3. Rate of Return Calculations for HL#2a. **(000 JD)**
(85% fruit trees 15% vegetables-Breakeven on O&M)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Gov't investment	-2831	-7078	-4362											
Energy costs			-105	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294	-294
O&M			-165	-435.9	-435.9	-435.9	-435.9	-435.9	-435.9	-435.9	-435.9	-435.9	-435.9	-435.9
Gov't replacem't pipes & valves														
Engr'g design & super @ 20%														
Unforseen expend @ 10%														
On-farm investment			-4370											
On-farm replacement														
Own filter tanks, etc.														
Trickle lines, mulching, ec.								-600					-600	
Farm equip, truck													-2070	
Working capital			-350											
Planning & design @ 5%								-30					-130	
Unforseen expenditures 10%								-60					-270	
Crop establishment			-1050	-1050										
Total investment	-2831	-7078	-10402	-1780	-730	-730	-730	-1420	-730	-730	-730	-730	-3800	-730
Net benefits from fruit trees					-280	-280	-70	385	1050	1505	1575	1575	1575	1575
Net benefits from vegetables			130	365	365	365	365	365	365	365	365	365	365	365
Net cash flow	-2831	-7078	-10272	-1415	-645	-645	-435	-670	685	1140	1210	1210	-1860	1210

Note: excludes estimates of current dryland production and extension services because of their small magnitude; see text for a discussion.

Appendix Table E-4. Rate of Return to Farmers at HL#2a. (000 JD)
(85% fruit trees; 15% vegetables; Without Farmers Paying for Water)

Year	Project	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	Farmer's perspective			0	1	2	3	4	5	6	7	8	9	10	11
On-farm investment				-2185	-2185										
On-farm replacement															
Filter tanks, etc.															
Trickle lines, mulching, ec.									-600					-600	
Farm equip, truck														-2070	
Working capital				-175	-175										
Unforseen expenditures 10%									-60					-270	
Crop establishment				-1050	-1050										
Total investment				-3410	-3410	0	0	0	-660	0	0	0	0	-2940	0
Net benefits from fruit trees							-280	-280	-70	385	1050	1505	1575	1575	1575
Net benefits from vegetables					130	365	365	365	365	365	365	365	365	365	365
Net cash flow				-3410	-3280	365	85	85	-365	750	1415	1870	1940	-1000	1940
Discount factor @ 10%				1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505
Discounted values @ 10%				-3410	-2982	302	64	58	-227	423	726	872	823	-386	680
Discount factor @ 15%				1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472	0.2149
Discounted values @ 15%				-3410	-2852	276	56	49	-181	324	532	611	551	-247	417
Note: excludes estimates of current dryland production because of itss small magnitude ; see text for a discussion.															

Appendix Table E-5. Rate of Return to Farmers at HL#2a. (000 JD)
(85% fruit trees; 15% vegetables; With Farmers Paying @ 15 fils/cu mt)

Year / Project	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Farmer's perspective			0	1	2	3	4	5	6	7	8	9	10	11
On-farm investment			-2185	-2185										
On-farm replacement														
Filter tanks, etc.														
Trickle lines, mulching, ec.								-600					-600	
Farm equip, truck													-2070	
Working capital			-175	-175										
Unforseen expenditures 10%								-60					-270	
Crop establishment			-1050	-1050										
Total investment			-3410	-3410	0	0	0	-660	0	0	0	0	-2940	0
Net benefits from fruit trees						-280	-280	-70	385	1050	1505	1575	1575	1575
Net benefits from vegetables				130	365	365	365	365	365	365	365	365	365	365
Net cash flow			-3410	-3280	365	85	85	-365	750	1415	1870	1940	-1000	1940
Less water charge at 15 fils per 1,000 cu mt				-93	-185	-185	-185	-185	-185	-185	-185	-185	-185	-185
Net cash flow after water charge			-3410	-3373	180	-100	-100	-550	565	1230	1685	1755	-1185	1755
Discount factor @ 10%			1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505
Discounted values @ 10%			-3410	-3066	149	-75	-68	-342	319	631	786	744	-457	615
Discount factor @ 15%			1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472	0.2149
Discounted values @ 15%			-3410	-2852	276	56	49	-181	324	532	611	551	-247	417
Note: excludes estimates of current dryland production because of itss small magnitude; see text for a discussion														